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Biometric and carcass measurements in Santa Ines lambs fed dehydrated brewery residue[1]

Medidas biométricas e na carcaça de borregos Santa Inês alimentados com resíduo de cervejaria desidratado

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ABSTRACT - The aim of this study was to determine biometric measurements *in vivo* and in the carcass of Santa Ines lambs fed dehydrated brewery residue. Thirty-five Santa Ines lambs were used, approximately 70 days of age and with a mean initial body weight of 16.00±1.69 kg. The experimental design was completely randomised, with five levels of dehydrated brewery residue - DBR (0; 20; 40; 60 and 80%) added to the concentrated portion of the diet, with seven replications. The experimental diets consisted of Tifton-85 hay, soybean meal, ground maize, dehydrated brewery residue in the experimental proportions, dicalcium phosphate and a mineral base. The body condition score, thoracic girth and croup width were not influenced by the experimental diets, neither were the carcass measurements, except for croup circumference, chest width and leg compactness index (P>0.05). However, there was a decreasing linear effect on the carcass compactness index and ribeye area as the DBR was added to the diet. The morphometric measurements of croup height and width, and chest width can be used as an alternative for estimating the body weight at slaughter and the cold-carcass weight of Santa Ines lambs fed dehydrated brewery residue, as they show a high correlation with these variables.

Key words: Body condition. Carcass conformation. Correlation. *In vivo* measurements.

RESUMO - Objetivou-se determinar as medidas biométricas *in vivo* e na carcaça de borregos Santa Inês alimentados com resíduo de cervejaria desidratado. Foram utilizados 35 borregos da raça Santa Inês, com aproximadamente 70 dias de idade e peso corporal médio inicial de 16,00 ± 1,69 kg. O delineamento experimental utilizado foi o inteiramente casualizado, com cinco teores de inclusão do resíduo de cervejaria desidratado - RCD (0; 20; 40; 60 e 80%) adicionados à porção concentrada da dieta, com sete repetições. As rações experimentais foram compostas por feno de capim Tifton-85, farelo de soja, milho grão moído, resíduo de cervejaria desidratado nas proporções avaliadas, fosfato bicálcico e núcleo mineral. O escore da condição corporal, o perímetro torácico e a largura da garupa não foram influenciados pelas rações experimentais, bem como as medidas obtidas da carcaça, com exceção do perímetro da garupa, largura do tórax e o índice de compacidade da perna (P>0,05). Contudo, para o índice de compacidade da carcaça e a área de olho de lombo, verificou-se efeito linear decrescente à medida que o RCD foi adicionado à ração. As medidas morfométricas de altura e largura da garupa e largura do peito podem ser utilizadas como alternativa para estimar o peso corporal ao abate e da carcaça fria de borregos Santa Inês alimentados com resíduo de cervejaria desidratado, pois apresentam alta correlação com essas variáveis.

Palavras-chave: Condição corporal. Conformação da carcaça. Correlação. Medidas *in vivo*.

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INTRODUCTION

Supplementing confined animals with a concentrated diet improves their productive performance and carcass characteristics, as it provides the necessary nutrients to meet the energy and protein demand of the herd during periods of food scarcity, with emphasis on the use of alternative food sources, such as wet brewery residue (SOUZA *et al*., 2010). However, the low dry matter content (DM, 20 to 27%) accelerates the process of degradation, and reduces DM input by the animals, affecting their performance and, as a result, carcass characteristics (CARVALHO *et al*., 2017; CAVILHÃO *et al*., 2013; GILAVERTE *et al*., 2011).

Drying the wet brewery residue, considered a potential pollutant, allows it to be conserved for a longer period. This gives rise to dehydrated brewery residue, which might be characterised as a protein food as it contains, on average, 85% DM and 25% crude protein (CP) (CAVILHÃO *et al*., 2013), and is a possible alternative and low-cost source for replacing ingredients conventionally used when formulating diets. However, it is important to assess its addition to the animal diet, since, under a production system, the diet, and consequently, the nutrients provided by the diet, directly influence animal performance relative to the growth of body tissue, and have a significant effect on the characteristics of the resulting carcass.

In animal production, assessing the carcass can be a way of estimating meat quality, carcass yield and profitability; the carcass should be evaluated based on weight, finish, length and ribeye area, among other characteristics (SANTOS *et al*., 2018). In addition, some carcass measurements may have a high correlation with the weight, and can be used as indicators of yield and quality, as adopted in systems for classifying sheep carcass (PINHEIRO; JORGE; YOKOO, 2010). However, studies are needed to evaluate these measurements, both *in vivo* and in the carcass, in order to determine which measurements would best indicate carcass yield and quality.

The aim of this study, therefore, was to determine biometric measurements *in vivo* and in the carcass of Santa Ines lambs fed dehydrated brewery residue in the concentrated portion of the diet, as well as to determine correlations between the measurements.

MATERIAL AND METHODS

The study was carried out in accordance with the ethical standards recommended by the Ethics Committee on Animal Research (CEUA), of the Federal University of Ceará, Fortaleza (Protocol No 36/2015).

The experiment was carried out in the Digestibility Sector of Animal Science Department at the University of Ceará - UFC, in Fortaleza. The city of Fortaleza is located in the coastal zone, at 30º43’0” S and 38º32’35” W, at an altitude of 15.49 m; the mean annual precipitation is 1,378.3 mm. The experiment lasted 74 days, from April to July 2015. During the study, the mean temperature inside the bays was 25.71 ºC with a relative humidity of 74.67%, data obtained from data loggers installed in the experimental shed.

Thirty-five Santa Inês lambs were used, approximately 70 days of age and with a mean initial body weight of 16.00 ± 1.69 kg. The animals were initially weighed, identified, vaccinated against clostridiosis and given vitamin complexes A, D and E. In order to standardise the health status of the lambs, they were wormed with two applications of an active ingredient based on Albendazole, 15 days apart. The animals were placed in collective pens for 15 days to adapt to the facilities and management, and then randomly distributed in the treatments, and taken to individual stalls with concrete floors lined with wood shavings and equipped with feeders and drinking fountains.

The experimental design was completely randomised, with five treatments and seven replications, where the treatments comprised the addition of 0; 20; 40; 60 and 80% dehydrated brewery residue to the concentrated portion of the diet. The experimental diets consisted of Tifton-85 hay, soybean meal, ground maize, dehydrated brewery residue, dicalcium phosphate and a mineral base.

The wet brewery residue was acquired from the brewing industry. It was placed on plastic sheets and exposed to the sun, turned every 60 minutes, and collected in the late afternoon, until approximately 80% DM was reached, determined as per the methodology described by the Association of Official Analytical Chemists (1990). After drying, the dehydrated brewery residue was weighed and packed in plastic bags to be added to the concentrated portion of the experimental diets.

The experimental diets were formulated according to the recommendations of the National Research Council (2007) for a mean weight gain of 200 g day^{-1}, at a roughage to concentrate ratio of 60:40 (Tables 1 and 2). The diets were offered twice a day (8 a.m. and 16 p.m.), allowing for leftovers of 10% of the total, with water available at will.

The body condition of the animals was assessed before slaughter by palpating the roughness of the transverse and dorsal processes of the lumbar vertebrae. The scores were assigned on a variable scale of from 1 to 5, with intermediate values of 0.5, considering a score of 1 for lean animals and 5 for obese animals (RUSSEL; DONEY; GUNN, 1969).

The morphometric evaluation was carried out as per Cezar and Sousa (2007), one day before slaughter, using a tape measure and a zoometric rule, with the animal kept upright in a pen. The following measurements were taken: body length (BL), comprising the cranial part of the greater tubercle of the humerus to the caudal part of the ischial tuberosity; withers height (WH), measured between the highest point of the interscapular region and the ground; croup height (CH), between the sacral tuberosity of the ilium and the ground; croup width (CW_L), the distance between the iliac tuberosities;

Table 1 - Chemical composition of the ingredients (g kg^{-1} DM)

Nutrients	Ingredients			
	Tifton-85 hay	Ground maize	Soybean meal	DBR[1]
Dry matter	928.75	934.01	944.81	937.90
Crude protein	74.69	87.69	493.64	288.74
Mineral matter	57.97	15.24	72.04	34.25
Organic matter	870.78	918.77	872.76	903.65
Ether extract	21.92	49.03	20.45	78.69
Neutral detergent fibre	826.35	169.36	130.73	562.05
Acid detergent fibre	444.17	67.80	78.20	155.25
Lignin	58.50	23.50	29.40	93.20
Non-fibrous carbohydrates	69.33	690.20	340.97	193.13

[1]Dehydrated brewery residue

Table 2 - Percentage and chemical composition of the experimental diets

Ingredients (% NM[1])	Dehydrated brewery residue[2]				
	0	20	40	60	80
Tifton-85 hay	60	60	60	60	60
Ground maize	27.60	22.80	18.20	13.44	6.80
Soybean meal	11.20	8.00	4.60	1.36	0.00
Dehydrated brewery residue[2]	0.00	8.00	16.00	24.00	32.00
Dicalcium phosphate[3]	0.20	0.20	0.20	0.20	0.20
Mineral base[4]	1.00	1.00	1.00	1.00	1.00
Chemical composition (g kg^{-1} DM)					
Dry matter	930.85	931.62	931.56	931.52	931.69
Crude protein	135.78	140.27	138.91	142.79	140.13
Mineral matter	59.36	58.53	56.26	56.94	54.55
Organic matter	940.64	941.47	943.74	943.06	945.45
Ether extract	30.52	34.01	38.77	40.81	42.35
Neutral detergent fibre	517.39	541.69	566.15	590.49	613.22
Acid detergent fibre	280.94	338.00	344.92	354.63	382.40
Lignin	50.13	83.14	93.95	108.11	118.78
Non-fibrous carbohydrates	256.95	225.50	199.91	168.97	149.75
Total digestible nutrients	518.14	491.40	491.36	533.18	537.15

[1]Natural matter; [2]Dehydrated brewery residue added to the concentrated portion of the diet; [3]Ca 24%; P 18%; [4]Ca 7.5%; P 3%; Fe 16,500 ppm; Mn 9,750 ppm; Zn 35,000 ppm; I 1,000 ppm; Se 225 ppm; Co 1,000 ppm

chest width (WC), the horizontal distance between the lateral surfaces of the humeral head; croup length (CL), the vertical distance between the two coxal tuberosities; and the thoracic girth (TG), measured at the outer circumference of the thoracic cavity, passing through the sternum, close to the axillae, and through the spinal processes of the thoracic vertebrae.

The animals were weighed weekly. The length of the experiment was determined as the time necessary for the mean body weight (BW) in any one of the treatments to reach 28 kg, at which time all the animals were slaughtered. Prior to slaughter, the animals were weighed to determine body weight, after which they were fasted for 18 hours and again weighed to obtain the body weight at slaughter (BWS).

The animals were slaughtered at a commercial slaughterhouse, where they were rendered unconscious by stunning in the atlanto-occipital region, and then bled by carotid and jugular section. The carcass were then transported to a cold room where they remained for 24 h at 4 °C. After the cooling period, the carcass were weighed to determine the cold-carcass weight (CCW).

With the aid of a tape measure and an anthropometric rule the following measurements of the lamb carcass were taken: external carcass length (ECL), the distance between the base of the tail (last sacral vertebra) and the base of the neck (last cervical vertebra); croup circumference (PC), the circumference of this anatomical region, taking the trochanter of both femurs as reference; thoracic depth (TD), the maximum distance between the sternum and the back of the carcass; internal carcass length (ICL), the maximum distance between the anterior edge of the ischio-pubic symphysis and the anterior edge at the midpoint of the first rib; leg length (LL), the distance between the centre of the perineum and the anterior extremity of the tarsometatarsal articular surface along the inside of the leg; croup width (CW_C), the maximum width between the trochanter of both femurs; and chest width (WC), the distance between the forelimbs (CEZAR; SOUSA, 2007).

The carcass compactness index (CCI) and leg compactness index (LCI) were determined using the following formulae: CCI = CCW/CIC and LCI = LG / LL (CEZAR; SOUSA, 2007). The ribeye area (REA) was determined in the left half-carcass, making a transverse cut between the 12 th and 13 th ribs to expose the area of the *Longissimus dorsi* muscle. To measure the REA, the outline of the muscle was traced onto transparent plastic film, as per the methodology described by Muller (1987). Using a rule and a permanent marker, two lines were drawn on the image of the *Longissimus dorsi* muscle, one that measured the maximum lateral-medial distance of the muscle, corresponding to the width (measurement A) and the other perpendicular to that, measuring the maximum dorsoventral distance, corresponding to the length (measurement B), as per the methodology described by Cezar and Sousa (2007). The mean values were then inserted in the formula to determine the ribeye area (REA), expressed in cm²: REA = (A/2 x B/2) x π, where π = 3.1416.

The results were analysed by analysis of variance, using the PROC GLM procedure of the SAS v. 9.1 software (Statistical Analysis System Institute, 2003). To study the correlations between the *in vivo* and carcass measurements, as well as the body weight at slaughter and the cold-carcass weight, Pearson’s correlation was used, employing the PROC CORR procedure of the SAS software. The data were submitted to regression analysis, using the PROC REG procedure of the SAS software, as per the following statistical model:

$Y = m+D_{ijk}+e_{ijk}$

where:

Y = observation;

μ = mean value of the observation;

D = Diet used (0; 20; 40; 60 and 80% dehydrated brewery residue added to the concentrated portion);

ε = Random error.

RESULT AND DISCUSSION

There was no effect on the body condition score ($P>0.05$; Table 3) from the addition of dehydrated brewery residue (DBR) to the concentrated portion of the diet, despite the body weight at slaughter showing a significant linear decrease ($P<0.05$). The animals fed diets containing more added DBR showed less weight when slaughtered than those that received no residue or when less residue was offered, possibly due to the high fibre content of the by-product (562.05 g kg^{-1} DM neutral detergent fibre; Table 1), which may have led to ruminal repletion, interfering in nutrient intake needed for better lamb performance. Pires *et al*. (2006) found that lambs fed diets containing increasing levels of neutral detergent fibre showed an increase in the number of days needed to reach the slaughter weight.

Similar behaviour to that of the body condition score was seen for the *in vivo* morphometric measurements of thoracic girth and croup width, which were not influenced by the addition of DBR to the concentrated portion of the diet ($P>0.05$). According to Pinheiro and Jorge (2010), croup width can indicate a larger proportion of muscles in the leg cut, and is an important characteristic in sheep destined for slaughter, since the leg is one of the most noble and more-valued cuts of the sheep carcass.

The values obtained for withers height, croup height, body length, croup length and chest width in the lambs showed decreasing linear behaviour with the addition of dehydrated

Table 3 - Body weight at slaughter (kg), body condition score and *in vivo* morphometric measurements (cm) in Santa Ines lambs fed dehydrated brewery residue

Variable	Dehydrated brewery residue					SEM[1]	P-value
	0	20	40	60	80		
Body weight at slaughter[2]	28.59	28.06	26.59	25.07	25.53	0.3201	0.0003
Body condition score	2.18	2.18	2.14	2.21	1.86	0.1414	0.1845
Thoracic girth	66.86	65.86	64.57	66.00	66.00	1.0268	0.6319
Withers height[3]	58.49	58.91	58.00	57.34	54.23	0.9407	0.0020
Croup height[4]	58.96	59.89	58.37	57.23	56.91	0.9126	0.0263
Body length[5]	60.56	61.30	58.53	58.34	58.33	0.9721	0.0222
Croup width	15.76	16.07	15.41	15.43	15.43	0.3570	0.2586
Croup length[6]	15.93	15.70	14.46	15.09	14.46	0.4434	0.0183
Chest width[7]	15.53	15.53	14.83	14.47	14.20	0.3145	0.0008

[1]Standard error of the mean; [2]$\hat{Y} = 30.4600 - 1.7365X$ ($R^2 = 0.33$); [3]$\hat{Y} = 59.4114 - 0.0504X$ ($R^2 = 0.73$); [4]$\hat{Y} = 59.6200 - 0.0337X$ ($R^2 = 0.76$); [5]$\hat{Y} = 60.8943 - 0.0371X$ ($R^2 = 0.69$); [6]$\hat{Y} = 15.8314 - 0.0175X$ ($R^2 = 0.67$); [7]$\hat{Y} = 15.6543 - 0.0186X$ ($R^2 = 0.94$)

brewery residue to the diet (P<0.05), which is possibly related to the lower body weight of the animals submitted to the corresponding treatments. This disagrees with the results of Cavilhão *et al*. (2013), who evaluated Santa Ines lambs fed 0; 20; 40 and 60% brewery residue, and found no effect from this ingredient added to the concentrate on the *in vivo* measurements of animals slaughtered at a body weight of 35.00, 33.13, 32.63 and 28.75 kg respectively.

Despite the effect seen in the present study, the percentage reduction in measurements was not considerable, since for every 1% additional DBR, there was a reduction of 0.0504, 0.0337, 0.0371, 0.0171 and 0.01857 cm respectively in withers height, croup height, body length, croup length and chest width. This may have been due to the difference in the final body weight of the animals, since, according to Marques *et al*. (2008), morphometric measurements are little influenced by nutritional management when the animals have the same weight at slaughter.

It is important to note that morphometric characteristics determine carcass conformation, particularly in relation to body tissue composition i.e. the deposition of muscular tissue, especially in the regions that comprise the noble cuts of the carcass, such as the shoulder and the leg (CEZAR; SOUSA, 2007). The linear decrease seen in the morphometric carcass measurements in the present study, may suggest that the addition of DBR to the concentrate can have a negative influence on obtaining a carcass with the desirable characteristics. In addition, several factors, such as the age of the animals, can influence performance and, consequently, the deposition of muscle tissue and the carcass characteristics. Gilaverte *et al*. (2011) concluded that the inclusion of wet brewery residue in the diet of growing Santa Ines sheep reduces the average daily gain of the animals. However, the authors used animals of 11 months of age and with a body weight of 48 kg, which must have been at the deposition stage of adipose tissue, reducing feed efficiency. It is therefore essential to evaluate the results considering the growth-curve phase of the animals.

With the inclusion of the different levels of DBR, a quadratic effect was seen for croup circumference, and a decreasing linear effect (P<0.05) for thoracic width. However, there was no influence (P>0.05) from the addition of DBR to the diets on the other characteristics under evaluation: external carcass length, internal carcass length, thoracic depth, croup width or leg length (Table 4).

Souza *et al*. (2010) found an increasing linear effect on external carcass length, thoracic width, thoracic depth and croup circumference, when evaluating the addition of concentrate (0, 0.66, 1.33 and 2.00% of body weight) in the diet of Santa Ines lambs kept under rotational grazing. The differences found in the above study can be explained by the age (12 months) and variation in body weight at slaughter (26.4 to 36.32 kg) of the animals; whereas in the present study the animals were 70 days old and were slaughtered at weights that ranged from 25.53 to 28.59 kg.

The neck and limbs correspond to the earliest developing regions in the animal (BENHCLIA *et al*., 2016), and therefore no significant difference was expected in leg length, as this is directly related to the development of bone-tissue.

There was no effect (P>0.05) on the leg compactness index, however, as the DBR levels in the experimental diets increased, there was a decreasing linear effect (P<0.05) on the carcass compactness index and ribeye area (Table 5).

Table 4 - Morphometric measurements in the carcass (cm) of Santa Ines lambs fed dehydrated brewery residue

Variable	Dehydrated brewery residue					SEM[1]	P-value
	0	20	40	60	80		
External carcass length	49.57	48.86	47.71	47.86	47.29	0.9265	0.0669
Internal carcass length	47.71	47.86	47.00	46.29	46.29	0.8595	0.1137
Thoracic depth	21.86	21.71	22.86	21.43	20.86	0.5421	0.1925
Croup width	16.04	16.84	16.39	15.77	15.30	0.5221	0.1319
Croup circumference[2]	50.71	53.29	53.00	52.14	50.57	1.1369	0.0460
Leg length	41.00	39.57	39.86	38.57	39.57	0.1339	0.2906
Thoracic width[3]	18.41	17.86	16.49	16.46	16.31	0.6103	0.0069

[1]Standard error of the mean; [2]$\hat{Y} = 50.9633 + 0.1194X - 0.00158X^2$ ($R^2 = 0.91$); [3]$\hat{Y} = 18.2257 - 0.0280X$ ($R^2 = 0.85$)

Table 5 - Carcass compactness index (CCI), leg compactness index (LCI) and ribeye area (REA) in Santa Ines lambs fed dehydrated brewery residue

Variable	Dehydrated brewery residue					SEM[1]	P-value
	0	20	40	60	80		
CCI[2] (kg cm^{-1})	0.22	0.21	0.20	0.19	0.19	0.0055	<0.0001
LCI	0.39	0.43	0.41	0.41	0.39	0.0204	0.8264
RAE[3] (cm^2)	8.64	8.34	8.30	7.66	7.51	0.3848	0.0219

[1]Standard error of the mean; [2]$\hat{Y} = 0.2191 - 0.00041X$ ($R^2 = 0.99$); [3]$\hat{Y} = 8.6800 - 0.0147X$ ($R^2 = 0.93$)

The decreasing linear effect found for the ribeye area was also seen by Urbano *et al*. (2015) with the addition of cassava juice to replace maize in the diet of Santa Ines sheep. The authors state that the result is consistent with a reduction in slaughter weight, a fact also seen in the present experiment, since this correlates with the amount of muscle in the carcass. The results of Carvalho *et al*. (2017), reinforce this, as they found no effect on slaughter weight or ribeye area when evaluating the addition of wet brewery residue for finishing Suffolk lambs in confinement.

The carcass compactness index is considered an indirect measure of conformation obtained from the ratio between the cold-carcass weight and the internal carcass length, which is used to evaluate muscle production in animals of similar body weight and tends to be higher in animals of greater weight, which could explain the effect seen in the present study, since, as mentioned above, the animals had significantly different body weights at slaughter ($P<0.05$). According to Fernandes Júnior *et al*. (2015), as this index is easily determined, it could be used to characterise the age at slaughter of Santa Ines animals.

The values found for the CCI were close to the 0.23 kg cm^{-1} seen by Cavilhão *et al*. (2013), when evaluating Santa Ines sheep fed with brewery residue as a replacement for soybean meal; however, the authors found no effect ($P>0.05$) from the addition of the residue on this variable.

The decreasing linear effect ($P <0.05$) seen for the REA, may be closely related to the slaughter weight. According to Cartaxo *et al*. (2011), this parameter, together with subcutaneous fat thickness and marbling, is related to daily weight gain, carcass yield and early finishing, and can be measured using ultrasound, which, according to Santos *et al*. (2018), is a non-invasive method that can be used to estimate the amount of fat and muscle mass *in vivo*, as these show a high degree of repeatability with carcass measurements.

The *in vivo* measurements that showed a high correlation ($P<0.05$) with body weight at slaughter were croup height (0.67), croup width (0.59) and chest width (0.79; Table 6). Correlated with the cold-carcass weight ($P<0.05$) were croup height (0.58), croup width (0.57), chest width (0.84) and body weight at slaughter (0.92).

The carcass measurements that showed a high correlation ($P<0.05$) with the body weight at slaughter were external carcass length (0.58), internal carcass length (0.60) and chest width (0.51), and with the cold-carcass weight were the external (0.58) and internal (0.71) carcass length. Among the variables studied in the present experiment, only leg length showed no correlation with any of the variables ($P>0.05$).

Table 6 - Correlation between *in vivo* measurements and carcass measurements in Santa Ines lambs fed dehydrated brewery residue

	In vivo measurements								Carcass measurements					
	TG	WH	CH	BL	CWL	CL	WC	BWS	ECL	ICL	TD	CWC	PC	TW
WH	0.02													
P-value	0.898													
CH	0.18	0.40												
P-value	0.304	0.017												
BL	0.28	0.33	0.23											
P-value	0.103	0.051	0.178											
CWL	0.53	0.05	0.21	0.40										
P-value	0.001	0.788	0.236	0.018										
CL	0.45	0.34	0.22	0.57	0.45									
P-value	0.006	0.045	0.202	<0.001	0.007									
WC	0.37	0.43	0.43	0.52	0.55	0.49								
P-value	0.031	0.009	0.010	0.001	0.001	0.003								
BWS	0.46	0.39	0.67	0.40	0.59	0.44	0.79							
P-value	0.006	0.022	<0.001	0.018	<0.001	0.008	<0.001							
ECL	0.26	0.48	0.57	0.46	0.28	0.56	0.52	0.58						
P-value	0.127	0.004	<0.001	0.006	0.100	0.001	0.001	<0.001						
ICL	0.26	0.28	0.60	0.30	0.48	0.34	0.55	0.60	0.54					
P-value	0.128	0.105	<0.001	0.083	0.003	0.046	0.001	<0.001	0.001					
TD	0.04	0.42	0.44	0.21	0.20	0.20	0.30	0.36	0.45	0.45				
P-value	0.810	0.012	0.008	0.235	0.253	0.257	0.079	0.036	0.007	0.007				
CWc	0.39	0.16	0.27	0.18	0.49	0.31	0.50	0.43	0.16	0.44	0.16			
P-value	0.021	0.352	0.120	0.305	0.003	0.071	0.002	0.010	0.370	0.007	0.356			
PC	0.09	0.26	0.31	0.10	0.47	0.11	0.56	0.45	0.19	0.31	0.24	0.61		
P-value	0.623	0.138	0.074	0.576	0.004	0.513	<0.001	0.007	0.272	0.066	0.163	<0.001		
TW	0.23	0.24	0.29	0.30	0.36	0.20	0.18	0.51	0.27	0.20	0.09	0.25	-0.09	
P-value	0.185	0.166	0.091	0.080	0.036	0.244	0.300	0.002	0.122	0.272	0.620	0.140	0.615	
CCW	0.43	0.41	0.58	0.45	0.57	0.48	0.84	0.92	0.58	0.71	0.36	0.48	0.45	0.40
P-value	0.009	0.015	<0.001	0.006	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	0.036	0.004	0.006	0.017

TG = thoracic girth; WH = withers height; CH = croup height; BL = body length; CW_L = *in vivo* croup width; CL = croup length; WC = chest width; BWS = body weight at slaughter; ECL = external carcass length; ICL = internal carcass length; TD = thoracic depth; CW_C = croup width of the carcass; PC = croup circumference; TW = thoracic width; CCW = cold-carcass weight

Considering the *in vivo* measurements under evaluation, those that showed the best correlation with body weight at slaughter and cold-carcass weight were croup height, croup width and chest width, all of which can be used to estimate the body weight at slaughter and cold-carcass weight with greater precision. Similarly, Pinheiro and Jorge (2010) obtained a greater correlation for chest width and croup width, however, they also found a greater correlation with thoracic girth, concluding that the three measurements could be used to estimate the slaughter weight and chilled carcass weight more accurately in Santa Ines discard sheep with a mean age of six years and mean body weight of 43 kg.

It is important to note that numerous factors can influence the correlation between the *in vivo* and carcass measurements, leading to greater error or low correlations; these include the presence of wool on the animal, the type of equipment used, the skill of the technician, the thickness of subcutaneous fat, the muscle area, the age of the animal and the position of the animal when the data is collected, in addition to a change in the proportion of carcass tissue, the removal of subcutaneous fat close to the skin when skinning, and incorrectly cutting the section measured *in vivo* (PINHEIRO; JORGE; YOKOO, 2010).

The carcass is essentially composed of bone, muscle and adipose tissue, whose proportion is influenced by such factors as genetic group, sex class and nutritional management (SOUZA *et al*., 2019). With regard to the effect of nutrition on nutrient composition, both protein and energy have a determining effect on the proportion of body tissue. Protein has a crucial role in the animal organism, participating in tissue formation and maintenance, muscle contraction, nutrient transport and in the synthesis of hormones and enzymes. Any energy deficiency in the diet can result in delays to growth, weight gain and other performance parameters, and it is considered critical to adjust the content when offering diets with a high proportion of fibre to ruminants (SILVA *et al*., 2010). The high fibre content of the DBR may have influenced *in vivo* and carcass biometric measurements due to the lower input of energy from the treatments containing the highest levels of added by-product.

CONCLUSIONS

1. Dehydrated brewery residue added to the concentrated portion of the diet in increasing levels negatively influences the biometric characteristics of Santa Ines lambs;
2. Based on the correlation found in the present study, the morphometric measurements of croup height, croup width and chest width can be used as an alternative for estimating the body weight at slaughter and the cold-carcass weight.

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